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Towards the determination of displacements in the Upper Rhine Graben area using GPS measurements and precise antenna modelling

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Abstract

The Upper Rhine Graben is a north-northeast trending rift system, which belongs to the European Cenozoic Rift System. Today, the southern part of the graben is seismically still active. Earthquakes of magnitude 5 have a recurrence time of approximately 30 years.

The EUCOR-URGENT project focuses on the seismic hazards and neotectonics in the Upper Rhine Graben and the surrounding areas. Within the framework of this project five institutions have created and have been maintaining a GPS network in the Upper Rhine Graben and the surrounding area in order to monitor horizontal and vertical displacements in the study area.

Two GPS campaigns have been carried out in the network to monitor and to determine the horizontal and vertical displacements in the study area. The first one was observed in 1999 and the second one in 2000. In 2002, 2 weeks of data of the available permanent GPS reference stations in the area have also been included in the investigations. These permanent stations belong to the European Reference Frame Permanent Network, International GPS Service network, Satellite Positioning Service of Baden-Württemberg, Réseau GPS Permanent-France (RGP), Réseau GPS Permanent dans les Alpes (REGAL) and the AGNES (operated by the Swiss Positioning Service). Due to the small size of the displacements expected, high accuracy requirements must be met in the GPS processing. In order to achieve this, the results of the available absolute antenna calibrations have been considered in the data processing, too.

The results have shown that the application of absolute antenna calibration models is crucial for the derivation of a highly accurate displacement field. Without these models large discrepancies (on the level of few centimetres) can be observed at those stations, where the observations were carried out by different antennas in the various campaigns.

As expectedly, due to the short time span, no significant displacement could be detected in the study area. However, the deformation analysis shows that the horizontal displacements do not exceed the level of 1 mm/yr. This value agrees with the results of other investigations.

1. Introduction

The Upper Rhine Graben forms a part of a Cenozoic rift system that extends from the North Sea towards the Western Mediterranean. The Upper Rhine Graben (Fig. 1) is located between the Rhenish Massif and the Jura Mountains, and has a length of about 300 km and an average width of 40 km (Schumacher, 2002). A geological overview of the URG can be found in Illies (1974, 1977), Pflug (1982), Ziegler (1992) and Schumacher (2002). The southern URG is seismically still active. Earthquakes of magnitude 5 have a recurrence time of approximately 30 years (Behrmann et al., 2003). Historical evidences show that a devastating earthquake—MSK (Mercalli scale) greater than 9—occurred on 18 October 1356 (e.g. Mayer-Rosa and Cadiot, 1979).

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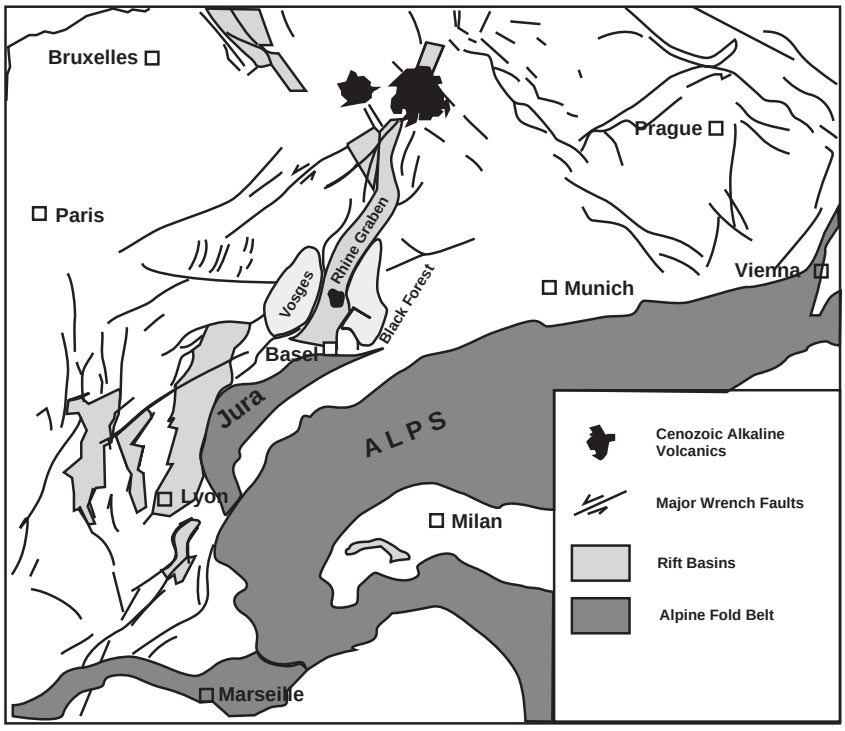

Fig. 1. Rhine Graben as a part of the European Cenozoic Rift System (ECRIS). Image modified from Ziegler (1992).

Schumacher (2002) states that during the rifting process the initial movement took place on ENE-WSW trending structures. He proposes that during the main rifting the motion took place on more NNE–SSW oriented structures. Most of the fault plane solutions of recent earthquakes in the southern URG suggest sinistral strike-slip kinematics along these north-north-east oriented steep movement planes (Behrmann et al., 2003) due to the NW–SE compressive stress regime in the area, which is caused by the Alpine collision.

In order to monitor the present displacements in the aforementioned area, a GPS network has been established and is being maintained by a group of universities and governmental agencies from France, Switzerland and Germany (CNRS Géosciences Azur Nice, Bureau de Recherches Géologiques et Miniéres Orleans, Geodesy and Geodynamics Lab of the Swiss Federal Institute of Technology Zürich, the Swiss Federal Office of Topography, the Geodetic Institute of the University of Karlsruhe and the Ordnance Survey of Baden-Württemberg).

The network has been measured two times, in 1999 and in 2000. In 2002, only the data of available permanent GPS reference stations have been processed.

Prior investigations carried out by Demoulin et al. (1998) using levelling data show that the expected vertical displacement rates are quite low, smaller than 1 mm/yr. Moreover, Nocquet and Calais (2003) estimated an upper bound of 0.6 mm/yr of the horizontal displacements in the Upper Rhine Graben. Due to the accuracy level of the GPS measurements, it is not expected to detect any significant tectonic displacements in the network within a short time span of 3 yr. However, at this stage, the results could at least confirm the level of the displacement rates in the investigated area.

On the other hand, the three measuring campaign enables us to assess the reliability of the network for the detection of displacements. To enhance this reliability, special care must have been taken of the correct modelling of the offsets and variations of the antenna phase centres.

2. The network

The sites of the GPS network can be classified in three major groups:

- campaign sites,
- permanent sites, and
- International GPS Service (IGS) permanent sites.

This network configuration enables us to detect the displacements with the optimal spatial- and time resolution.

The data of the permanent sites could be used for the continuous monitoring of the displacements using the co-ordinate time series of these stations. However, the spatial distribution of permanent reference sites is